NASA CR-170,845



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(NASA-CR-170845) PRELIMINARY ENGINEERING STUDY: QUICK OPENING VALVE MSFC HIGH REYNOLDS NUMBER WIND TUNNEL Final Report (Fluidyne Engineering Corp.) 50 p HC A04/MF A01 CSCL 14B G3/09

N83-31612

Unclas 28481

N83-31612 #

FluiDyne ENGINEERING CORPORATION

# PRELIMINARY ENGINEERING STUDY
# QUICK OPENING VALVE
# MSFC HIGH REYNOLDS NUMBER WIND TUNNEL

by

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prepared for

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Final Report
Contract NAS8-35056
FluiDyne Project 1380

July 1983

SUMMARY

FluiDyne Engineering Corporation has conducted a preliminary engineering study of a quick-opening valve for the MSFC High Reynolds Number Wind Tunnel under NASA Contract NAS8-35056. The subject valve is intended to replace the Mylar diaphragm system as the flow initiation device for the tunnel. Only valves capable of opening within 0.05 sec. and providing a minimum of 11.4 square feet of flow area were considered. Also, the study focused on valves which combined the quick-opening and tight shutoff features in a single unit. A "ring sleeve" valve concept was chosen for refinement and pricing. Sealing for tight shutoff, ring sleeve closure release and sleeve actuation were considered. The resulting cost estimate includes the valve and requisite modifications to the facility to accommodate the valve as well as the associated design and development work.

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# 1.0 PROJECT DESCRIPTION

## 1.1 Basic Project Description

This report covers the results from a preliminary engineering study of a project involving replacement of the Mylar burst diaphragm quick-opening valve used for flow initiation in the MSFC High Reynolds Number Wind Tunnel with a mechanical quick-opening valve. The High Reynolds Number Wind Tunnel at MSFC is a Ludwieg tube type tunnel whose basic operation is described in Reference 1. The MSFC tunnel is equipped with a 52 in. I.D. x 386 ft. long charge tube and has a 32 in. I.D. test section. Test Mach numbers range from 0.25 to 3.50 and include M = 1.0 which is the maximum mass flow rate configuration. Initial charge tube pressures of up to 650 psig are utilized. A complete description of the facility is given in Reference 2.

As noted above, flow initiation is currently accomplished using a Mylar burst diaphragm located just downstream of the facility's model support section. For operation with a 650 psig charge pressure (30) 0.014 in. thick Mylar disks are combined to form the diaphragm corresponding to a cost of $180 for the Mylar. Typical run conditions and run rates bring the annual cost for Mylar to about $90,000. The cost of the Mylar and the labor required to assemble and install new diaphragms and clean Mylar scraps out of the exit sphere has resulted in renewed interest in a mechanical quick-opening valve to replace the diaphragm system.

## 1.2 Design Criteria for Study Valve

The Mylar burst diaphragm assembly is compact, having an I.D. of only 48 in. and an overall length of only 36 in. (see Figure 1). Any mechanical replacement would likely occupy a

greater length and diameter. There are, in fact, a number of aerodynamic and structural design factors as well as cost which need consideration when designing a mechanical valve. These are reflected in the following design criteria list:

a. The valve must provide adequate internal flow area. (We interpret the maximum internal Mach number limitation of 0.3 to imply that the valve effective area should nowhere be less than 2.03 x the test section area or 11.4 sq. ft.).

b. The valve inlet I.D. should be 48 in. to match the exit diameter of the current model support section.

c. The valve outlet I.D. should be 48 in. to match either the current subsonic diffuser entrance or the sleeves which are used to connect the valve to the subsonic diffuser entrance.

d. The valve internal flow path should be designed to minimize total pressure losses through the valve (between the valve minimum area and the valve exit the nominal duct area should lie between 14 and 16 $ft.^2$ with gradual variations between the nominal area and the minimum or exit areas. Sharp edges and abrupt corners should be avoided).

e. The valve opening time should be short enough so that it doesn't significantly reduce the available run time (valve opening time of 0.015 sec. is desired but up to 0.05 sec. may be acceptable depending on instrumentation capability). The valve release and actuation system should provide the required opening times over the

full range of charge pressures. Note: quick closure is not essential.

f. To insure quiescent conditions within the charge tube prior to a run there shall be no significant air leakage through the valve system prior to initiation of quick-opening. (Thus the quick-opening valve must be capable of tight shutoff.)

g. The valve maximum outside diameter should remain within the confines of the current tension rod system (maximum O.D. approximately 88 in.).

h. The resulting valve assembly length should be such that the existing subsonic diffuser geometry can be essentially maintained. Due consideration should be given to the extent the track can be extended and provision of an enclosure over the seal joint in the diffuser. (Assuming that 6 ft. of motion is still required to open the tunnel, the longest valve assembly length which appears practical is about 16 ft. Ideally the valve assembly would not exceed 11 ft. in length.) Note that no major problem results from extending the tracks beyond the present building wall.

i. The resulting valve design should not influence loads on the tension rods or other retained existing tunnel components.

j. The quick-opening valve shall be designed and constructed in such a manner that annual maintenance and supply costs (seals, snubbers, actuators, expendable release devises, etc.) shall be less than 20% of the corresponding diaphragm replacement cost.

k. For safety reasons the quick-opening valve shell shall be designed and constructed to withstand a 650 psig internal pressure without yielding.

## 2.0 JUSTIFICATION

The replacement of the diaphragm in the High Reynolds Number Wind Tunnel (HRWT) with a quick-opening valve will increase the production rate of the facility and significantly reduce its operating costs both in manpower and materials. The increase in production rate will result from a faster turnaround between blows in the low and medium pressure ranges. In these ranges the changing of the Mylar diaphragm is the pacing item between runs. It is estimated that eliminating the diaghragm changing operation will increase the test rate by 15 to 20 percent.

The Mylar diaphragm material costs approximately $84,000 per year based on a cost of $420 per roll. The labor to cut the raw Mylar into the diaphragm configuration costs about $30,000 per year. Therefore, the elimination of the diaphragm will reduce the operating cost of the HRWT by about $114,000 per year. It is anticipated that the cost of the quick-opening valve will be amortized in four or five years with a 15 to 20 percent increase in facility output.

# 3.0 VALVE CONCEPT REVIEW

## 3.1 Perforated Sleeve Valve

### 3.1.1 Perforated Sleeve Valve with Separate Tight Shutoff Valve

#### 3.1.1.1 4 Ft. x 4 Ft. Perforated Sleeve Valve (Background)

The FluiDyne perforated sleeve valve (Figure 2) was initially considered as a candidate to meet the quick acting requirements of the MSFC tube tunnel application. This valve was developed for use as an emergency shut-off valve for the 4 ft x 4 ft trisonic tunnels. It was located between the air storage tanks and the main tunnel control valve. Actuation was pneumatic (tank storage air) and was initiated by an explosive squib upon signal from the tunnel interlock and safety system. Actuation time was approximately 10 milliseconds. Later versions of the 4 ft x 4 ft tunnel use this valve as both the main tunnel control valve and the emergency shut off valve. It is hydraulically servo operated with separate control circuits for the pressure control and the emergency shut-off operations. Because the valve inherently is not a tight shut-off valve, isolation valves are located upstream. These are relatively slow acting (2 to 4 seconds) tight shut-off ball valves.

#### 3.1.1.2 Tight Shut-Off Valve Concepts

Several types of tight shut-off valves were investigated to be used in series with the perfcrated sleeve valve:

- gate
- ball
- butterfly

Design requirements are 48 in. size, 650 psi, and 2 to 4 second actuating time.

The gate and ball valve configurations produced fully open flow paths, whereas the butterfly had a residual central blockage (disk in the open position). Manufacturers were contacted to get dimension, weights and price information.

The gate and ball valves have been built in this general pressure and size range, however, they are large (7 ft long, 14 ft high) and costly. A copy of a quote on a gate valve is included in the Appendix. This valve plus a hydraulic actuator, power supply and controls is estimated to cost approximately $120,000. Ball valves for this rating are estimated to be of the same overall length and cost.

Butterfly valves were investigated also. Valves of this size (48 inch) and pressure rating (650 psi) have not been built to our knowledge. Although the size (and cost) of the sandwich type configuration would be considerably less than the ball or gate valves, the blockage created by the disc appears to be in the 30 to 40% range which is considered unacceptable from an aerodynamic standpoint.

#### 3.1.1.3 MSFC Perforated Sleeve Valve

An adaptation of the perforated sleeve valve to the MSFC tube tunnel is shown on Drawing SK1380-702. It is shown together with a tight shut-off butterfly valve, both located

between the model support section and the diffuser. In order to minimize ducting and housing requirements, the sleeves are oriented parallel to the flow with the air entering axially from one end. The actuation was changed from a rotational motion to an axial motion in order to package the actuator inside the valve thus eliminating the housing penetration, linkage and actuating arm.

The outer sleeve is the stationary structural member supporting the downstream pressure head and actuator. The inner sleeve is the thinner, lighter member which moves axially for opening or closing. The actuator connects directly to the sleeve through 4 radial struts.

The hole pattern consists of 16 circumferential rows of 3-inch diameter holes with 22 holes per row for a total of 352 holes with a geometric open area of 17.3 $ft^2$. If 4-inch diameter holes were used, a total of 192 holes would be required, the sleeves would be about the same length and travel would be increased to approximately 4-1/2 inches.

The actuator would be either a pneumatic or hydraulic cylinder.

#### 3.1.1.4 Evaluation of Perforated Sleeve Concept with Separate Tight Shutoff Valve

During the meeting held at MSFC on 19 May, the separate perforated sleeve/tight shut-off configuration (Drawing SK1380-702) was discussed and tunnel operating requirements further clarified. The results are summarized as follows:

a. The separate tight shut-off/quick-opening configuration is not feasible from several standpoints.

- Separate tight shutoff and quick-opening valves will result in more new hardware, more modification to existing hardware and thus higher cost than single quick-opening - tight shutoff valve concepts

- Leakage during slow opening of a separate tight shutoff valve will lower the maximum stagnation pressure

- Leakage during slow opening of a separate tight shutoff valve will create disturbances in the charge tube.

b. Remaining effort on this contract should be concentrated on a single tight shut off, quick-opening valve.

c. Relaxed opening times can be considered. (.05 sec. max.)

d. Quick closing is desirable but not mandatory.

### 3.1.2 Perforated Sleeve Valve with Tight Shutoff Capability

#### 3.1.2.1 Cylindrical Perforated Sleeve

Attempts to make the perforated sleeve tight shut off produced these sealing concepts:

a. Elastomeric O-ring type seals around each of the 352 4 in. dia. holes. Problems are as follows:

- Large total length of seal (approximately 460 ft) resulting in a large friction force opposing movement.

- High probability of leakage since each seal must pass over an open hole.

- Cost of machining the grooves into the curved surface of the cylinder.

b. Teflon (or similar material) sleeves located in each hole accomplishing a seal with the adjacent sleeve. Problems are similar to those listed above plus the difficulty in providing the sealing force (as compared to O-rings which are self-energizing).

3.1.2.2 Conical Perforated Sleeve

By changing the sleeves from cylindrical to conical, a tight seal could possibly be accomplished by forcing the 2 sleeves together axially. This would require very accurate machining of the mating surfaces and most likely a resilient material (teflon or similar material) on one of the surfaces to accomplish the sealing. The differential pressure-area of the two ends of the cone would produce an axial thrust which could be used to initiate the opening motion of the outer sleeve. Problems with this concept are as follows:

- A large axial upstream force would be needed to balance the pressure area term plus produce high surface compressive stresses to accomplish sealing.

- The mass of the outer sleeve, which is the primary structural element, is quite large. This affects both acceleration and deceleration mechanisms.

#### 3.1.2.3 Evaluation of Tight Shutoff Perforated Sleeve Concepts

The mass of the movable sleeve in this valve concept is very large creating acceleration and snubbing problems. Providing tight shutoff with the large number of holes inherent in such a valve is uncertain even with considerable development.

## 3.2 Non-Perforated Cylindrical Sleeve Valve (Ring Type Sleeve Valve (Ring Type Sleeve Valve)

### 3.2.1 Ring Type Sleeve Valve Background

Because of the difficulties in sealing and actuating the perforated sleeve concepts, effort was turned towards investigating a configuration in which a solid sleeve moves axially to open an annular passage. Although the travel distance of the sleeve would be longer, the sleeve would be much lighter in weight than the perforated sleeve and the sealing would be accomplished by two full circumferential seals.

This solid sleeve concept is not new. A variation of it was investigated as one of several concepts studied during the initial valve study done by FluiDyne for MSFC in 1966 (see Figure 3). The main concerns identified were methods of sealing and the release and actuating mechanisms. This basic concept is used as the main pressure control valve on the Ottawa 5 ft wind tunnel (see Figure 4). Also, a similar configuration (actually a slid-

ing plug) is presently installed as the main pressure control valve in the Douglas 4 ft x 4 ft trisonic tunnel (see Figure 5).

### 3.2.2 Preliminary Evaluation of Ring Sleeve Concept

Since the ring sleeve concept could be made "tight shutoff" by the use of only two circumferential seals and results in a sleeve mass much less than that of the perforated sleeve concept the perforated sleeve was abandoned and the ring sleeve concept chosen for development.

# 4.0 DESCRIPTION OF RECOMMENDED RING SLEEVE CONCEPT

## 4.1 Basic Valve Concept

### 4.1.1 General

The quick opening valve configuration recommended for the MSFC tube tunnel is shown on Drawing 1380-001. It employs a tight sealing solid sleeve which actuates axially to open an annular flow passage. Motion is powered by a pneumatic piston/cylinder to open the valve in less than .05 seconds. Deceleration of the moving parts is accomplished by a commercial hydraulic shock absorber. Several release concepts for initiating the motion are possible, however, further study is needed before selecting one.

The valve is enclosed in a 9 ft long housing positioned between the existing model support and diffuser sections as shown on Drawing 1380-002.

### 4.1.2 Detailed Description

The sleeve is attached to a central actuating rod by 4 radial struts. The rod, which contains the actuating piston at the downstream end is supported and guided by bearings at both ends. The upstream bearing is supported by 8 radial struts which also support a segmented deflector which directs the flow radially outward through the valve opening. An inner housing weldment with the actuator at the downstream end forms the 650 psi pressure boundary for the downstream end of the tunnel. It consists of a long flanged and dished head connected to an upstream flange by 12 support ribs. This is surrounded by an outer housing which forms the outer airflow boundary. This is designed for a much

lower pressure (250 psi), but also must withstand the compressive force created by the tunnel disconnect-tension rods.

#### 4.1.3 Flow Path Geometry

The flow area entering the valve is basically 12.6 $ft^2$ (48 in. dia.) less approximately 1.5 $ft^2$ for the shaft upstream bearing and support ribs for a net of 11.1 $ft^2$. This is larger than the open area of the cruciform structure of the existing diaphragm assembly (estimated at 8 $ft^2$).

The 48 in. O.D. by 20 in. long sliding sleeve opens a flow path radially outward, through the support ribs and axially downstream through the housing annular passage. Minimum flow area is 16.6 $ft^2$. The flow converges to the 48 in. diameter entrance to the diffuser with a net flow area of 12.0 $ft^2$ (deducting 0.6 $ft^2$ for the shock absorber body).

Motion of the sleeve is 26 in. total, including 2 in. pretravel, 16 in. opening travel, and 8 in. deceleration travel.

#### 4.1.4 Actuator

Because of the fast actuation requirements and resulting high actuator velocities, conventional hydraulic actuators were ruled out for this application. Several versions of pneumatic actuators utilizing either a stored energy source or a gas generator (pyrotechnic) have been considered.

The recommended actuator configuration is shown on Drawing 1380-001. It consists of an annular gas reservoir surrounding a 10 in. dia. pneumatic cylinder. The reservoir is sized at approximately 2 times the volume of the piston displacement.

Large parts located around the upstream circumference of the cylinder connect the reservoir to the cylinder. This reservoir is pressurized prior to actuation to provide the driving force for the piston. The magnitude of this force is greatest at initiation of motion, and decreases as the piston travels downstream. The piston travel is 18 in., which corresponds with the end of the opening travel of the sliding sleeve, i.e., the valve is wide open. At this point the piston is arrested (or stopped) by the end cap of the actuator (the rod can slide through the piston). The rod then contacts the plunger of the shock absorber which decelerates the rod/sleeve assembly during the remaining 8 in. of travel. By arresting the piston at the end of the valve opening travel, the driving force is eliminated during the deceleration travel, thus reducing the shock absorber loads. The actuator is reset (sleeve closed) by bleeding the air from the reservoir and pressurizing the downstream end of the actuator. The release mechanism can then be recocked, and the actuator reservoir charged in preparation for a subsequent run.

#### 4.1.5 Release Mechanism

Several release mechanism concepts were investigated, however, as mentioned earlier, a specific configuration has not been selected. The concepts included:

- Explosive bolts
- Hydraulic release
- Toggles, latches
- Overcenter linkages

Refer to Appendix A for the description of these concepts. This is an area requiring further study and possibly testing.

4.1.6 Seals

A full circumference seal is located in each end of the sliding sleeve. They seal with machined surfaces on the inner housing. The diameter of the downstream sealing surface is larger than the upstream sealing surface to assure that the seals travel clear of the mating surfaces after the first one inch of travel. As in the case of the release mechanism, several concepts have been investigated, but a specific configuration has not been selected. This too is an area identified for further study and testing. Refer to Appendix B for a description of these concepts.

4.1.7 Assembly

The major sub assemblies comprising the valve are:

- Sleeve, bearing and inner housing assembly
- Actuator-shock absorber assembly
- Outer housing

These sub assemblies can be fabricated and machined separately and assembled/disassembled as required. This will facilitate repair or replacement of seals, actuator, release mechanism, etc. as necessary.

4.1.8 Actuation and Controls

Preliminary calculations of the actuating forces, inertias, times, etc. are included in the calculation packages. The current configuration shown on Drawing 1380-001 has a valve opening time of approximately 0.05 seconds. This is based on an air reservoir charge pressure of 650 psi, an estimated weight of the

moving elements of 1200 lbs, and an opening travel of 16 in. Forces produced are 37,000 lbs (average) accelerating force, and 100,000 lbs decelerating force.

The controls envisioned would accomplish the following sequence of operations:

- Close the sleeve (move upstream)
- Arm the release mechanism
- Close the tunnel and energize the disconnect-tension rods.
- Pressurize the tunnel
- Charge the actuator gas reservoir
- Energize the release mechanism

All the equipment/systems required to accomplish the above operations plus the safety and interlock systems are necessary for a functioning valve system (refer to Figure 6).

### 4.1.9 Evaluation of Ring Sleeve Concept

#### 4.1.9.1 Loads

For the evaluation of loads it will be assumed that the tunnel is initially pressurized to 650 psig up to the ring sleeve and the actuator pressurized to 700 psia as illustrated in Figure 7a. As shown, the receiver sphere is assumed to be evacuated prior to flow initiation.

At sleeve release the actuation system rapidly pulls the sleeve aft, uncovering the opening to the annular duct which leads to the subsonic diffuser and receiver sphere. Flow is quickly established within the valve resulting in a distribution of pressures which are a function of:

a. the ratio of charge tube area to test section throat area (Reference 1)

b. the ratio of test section throat area to valve throat area (successive throats)

c. local Mach numbers within the valve $(P/P_{T_{valve}})$

For the present calculation of loads a Mach 1.0 tunnel configuration has been assumed (test section throat area 5.6 ft.$^2$) and the valve effective throat area has been assumed to be 10 ft.$^2$ The corresponding ratio of test section throat area to tube area is (32 in./52 in.)$^2$ = 0.38 giving a test section total pressure to initial charge pressure ratio of 0.78 based on Figure 2 of Reference 1 thus

$$P_{T_O} = 0.78 \times 6.65 = 519 \text{ psia}$$

and

$$P_{T_{valve\ max}} = 519 \times \frac{5.6}{10.0} = 290 \text{ psia}$$

Local effective flow areas in the annular duct passage within the valve may be as high as 16 sq. ft. corresponding to $A/A^* = 1.6$ and $P/P_{T_{valve}} = 0.9$ thus:

$$P_{shell\ max} = 290 \times 0.9 = 261 \text{ psia}$$

The resulting pressure loads on various parts of the valve during a run are shown in Figure 7b.

While complete blockage of the 48 in. diameter entrance to the existing subsonic diffuser is very unlikely we believe that in the interest of utmost safety it is wise to design the quick-opening valve shell to accept the full 650 psig charge pressure without yielding. Maximum pressure loads and thrust loads on existing tunnel components located upstream and downstream of the quick-opening valve will remain the same as they are now with the Mylar diaphragm system. Loads on the tension rods will also remain the same as current loads.

4.1.9.2 Performance

The primary performance goals for the quick-opening valve are to provide an adequate effective flow area

$$(A_{\substack{valve\\eff}} = 2.03 \times 5.6 = 11.4 \ \text{ft.}^2)$$

and a short opening time (opening time < 0.015 sec. desired but up to 0.05 sec may be acceptable).

Figure 8 shows the effective flow area distribution through the chosen ring sleeve valve configuration. Provision of close to the desired flow area seems practical. The sleeve velocity, position and effective open area versus time are shown in Figure 9. These values were calculated assuming a sleeve and strut assembly weight of 1200 lbm, a piston area of 71 in.$^2$ and an average $\Delta P$ across the piston of 650 psi. This actuation corresponds to the fastest opening times which we believe are practical from the standpoint of actuation forces and snubbing loads. From valve sleeve release to full open (18 in. of travel) requires 0.05 sec. however, the first 2 in. of travel do not result

in any net valve open area. Thus the time from 2 in. of travel (zero opening) to full opening requires 0.050 - 0.016 = 0.034 sec. Full opening corresponds to 14.5 ft.$^2$ effective area and the design criteria identify 11.4 ft.$^2$ as being an adequate effective area. From zero opening to 11.4 ft.$^2$ effective area requires 0.047 - 0.017 = 0.030 sec.

For reference we have the existing Mylar diaphragm opening time of 0.015 sec. On the other hand the current diaphragm section cruciform blockage and deflected Mylar blockage probably result in an effective area through the diaphragm section of only 8 or 9 sq. ft. (see Figure 10). Correspondingly the chosen ring sleeve valve concept will go from zero opening to 9 ft.$^2$ effective area in 0.026 sec.

The basic run time for the MSFC High Reynolds Number Wind Tunnel is nominally 0.55 sec. from the initiation of steady test conditions to the return of the leading expansion wave. A conservative view would be that a given increase in valve opening time would result in a corresponding decrease in useable run time. Thus the proposed ring sleeve valve concept would result in useable run times perhaps 0.011 to 0.015 sec. shorter than the diaphragm system (2% to 2.7% shorter).

## 4.2 Facility Modification and Installation Requirements

Several modifications to the facility are r cessary to incorporate the quick-opening sleeve valve. Based on the longest nozzle and the transonic test sections being in the circuit (existing spool pieces can be inserted when using shorter tunnel components), the following modifications are required:

- Remove the diaphram section,

- Remove spool pieces,
- Replace downstream sections of disconnect-tension rods with longer rods (4 pieces),
- Remove a portion to the cylindrical part of the fixed diffuser and reweld,
- Provide an enclosure or extension to the building wall around the diffuser,
- Relocate the support foundations for the hydraulic translation actuator and the diffuser support,
- Extend the tracks, including bases,
- Move the diffuser and hydraulic actuating cylinder downstream,
- Relocate hydraulic lines and instrumentation to the downstream disconnect-tension rods, and
- Install the quick-opening valve including associated controls and instrumentation.

The quick-opening valve assembly should be assembled and checked out apart from the facility. Installation of this assembly will require handling equipment for lifting approximately 20,000 lbs. Also, part of the two upper disconnect-tension rods must be removed to provide clearance to lower valve into positions.

In order to minimize facility downtime, some facility work can be done prior to shutdown. This includes the following:

- Fabricating the longer disconnect-tension rods,
- Constructing new and extended foundations for the tracks, diffuser and translation actuator, and
- Constructing the building extension,
- Preparation of interface for the hydraulic, air and instrumentation equipment.

# 5.0 FINAL DESIGN CRITERIA

## 5.1 Completed Project Scope

A mechanical quick-opening valve will replace the existing Mylar diaphragm quick-opening device in the George C. Marshall Space Flight Center High Reynolds Number Test Equipment (see description of current facility in Reference 2. The complete project will include requisite modification to the present facility in addition to provision of a mechanical quick-opening valve. The quick-opening valve shall be of the ring sleeve type. The basic valve concept and the corresponding facility modifications are illustrated in Drawings 1380-001 and 002.

## 5.2 Engineering Design Work Statement

The contractor shall prepare the design and specifications to accomplish procurement, installation and checkout of a mechanical quick-opening valve to replace the Mylar diaphragm quick-opening device in the George C. Marshall Space Flight Center High Reynolds Number Test Equipment. The design shall include the quick-opening valve itself as well as the associated control, release, actuation and snubbing systems. Also included in the design shall be modifications to the track, modifications to the diffuser, modifications to the building and design of new tension rods (refer again to Drawings 1380-001 and 002). The design criteria and requirements for the project are as follows:

### 5.2.1 Environment

650 psig fully charged tube pressure/ambient temperature air as test medium/10100 lbm/sec. maximum mass flow rate with 650 psig initial charge pressure and 530°R initial charge temperature

### 5.2.2 Valve Configuration

The valve shall be of the ring sleeve type as described in Drawing 1380-001 with:

4 feet inside diameter at upstream end

4 feet inside diameter at downstream end

7 feet 4 inch maximum outside diameter

11 feet maximum desired length

16 feet maximum tolerable length

11.4 $ft.^2$ minimum net flow area with valve open

14 $ft.^2$ to 16 $ft.^2$ nominal net flow area in the region between the valve minimum area and the exit

gradual variation between nominal net flow area and minimum or exit flow areas

(abrupt 90° corners in the flow path should be avoided)

### 5.2.3 Subsonic Diffuser Configuration

The existing subsonic diffuser geometry should be essentially maintained and the existing spacer spools remain in use.

### 5.2.4 Valve Actuation Time

A valve opening time of 0.015 sec. is desired. From a practical standpoint it may suffice if the valve is capable of going from zero opening to an effective flow area of 11.4 sq. ft. in no greater than 0.04 seconds. The actuation system shall perform as required over the entire range of initial charge tube pressures. Quick-opening is the only requirement. Manual closing is permissible.

5.2.5 Tight Shutoff Provision

Tight shutoff and quick-opening features shall be combined in one valve. A leak rate of up to 2.5 lbm/sec. is permissible through the closed valve at full charge pressure.

5.2.6 Pressure Loads on Valve

1. Fully Charged with Valve Closed

   665 psia inside closed ring sleeve and rest of centerbody

   0 psia surrounding closed ring sleeve and centerbody

2. Normal Running

   261 psia inside valve outer shell with 14.7 psia atmospheric pressure outside

3. Emergency with Valve Exit Blocked

   665 psia conservative

   615 psia minimum acceptable with 14.7 psia atmospheric pressure outside

5.2.7 Stress Criteria

5.2.7.1 General

Unless otherwise specified, all design safety factors for static loading shall be equal to or greater than a factor of

4 based upon the ultimate strength of the material, or a factor of 3 based on the yield strength. Typical values appear in the Table below.

| Material | Fy(ksi) | Fu(ksi) | F allowable (ksi) |
|---|---|---|---|
| A-36 | 36 | 58 | 12.0 |
| A-516 GR 70 | 38 | 70 | 12.7 |
| A-285 GR C | 30 | 55 | 10.0 |

Maximum allowable shear stress for static loading shall be taken as $\frac{1}{\sqrt{3}}$ times 2/3 of the tensile yield strength of the material. Allowable stress values for emergency load conditions shall be equal to the yield strength of the material.

5.2.7.2 Supplementary

Pressure Vessels

The design factors and weldment requirements for the pressure vessels shall be in accordance with the applicable section of the ASME Boiler and Pressure Vessel Code, Section 8, Division 1.

Welds

Stresses in welds of steel base materials shall conform to the allowables given in Section 1.5.3 and Appendix B of the AISC "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings."

Welded connection computations and construction shall follow the practices as outlined in the above specification.

Fasteners

Allowable stresses for steel fasteners shall be as specified in the AISC "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings."

Bolted joints shall be designed as bearing type connections. Shear loads, wherever possible, shall be transmitted by keys, pins, pilots, or shoulders to assure bolts are loaded in tension only.

Bolted joints which have the primary function of transmitting moments shall be designed such that the bolt preload divided by the joint contact area is at least 1.25 times the applied moment divided by the section modulus of the contact area. The bolt preload shall be taken to be one-half of its tensile yield strength.

Piping

Piping as used in this criteria includes pipe, flanges, bolting, gaskets, valves, relief devices, fittings and the pressure containing parts of other piping components. It also includes hangers and supports and other equipment items necessary to prevent overstressing the pressure containing parts. It does not include structures and equipment, such as pressure vessels, mechanical equipment and instruments.

The design of pressure piping components shall be in accordance with the latest edition of ANSI B31.1, "Power Piping."

The allowable stress values to be used for the design of power piping systems are given in Appendix A of ANSI B31.3, "Power Piping." The basis for establishing stress values in this Code Section are the same as those in the ASME Boiler and Pressure Vessel Code, Section VIII, Division I. Therefore, allowable stress values for materials not included in ANSI B31.1, "Power Piping," may be taken from Section VIII, Division I, of the ASME Boiler and Pressure Vessel Codes.

5.2.8 Valve Sleeve Control, Release and Actuation

- The triggering of the valve sleeve release shall be consistent with the current triggering system in terms of functions performed. Controls shall be located in the control room.

- Sleeve release may be accomplished by explosive bolt, toggle or other device. The system must meet the operating and maintenance cost limits defined below.

- The actuation system may utilize regulated high pressure air from the tube charge air supply.

5.2.9 Cost Limitations

1. The project design will not result in exceeding the maximum construction cost target of $500,000 in 1983 dollars unless express authorization for a higher cost project is given by MSFC.

2. The quick-opening valve shall be designed and constructed so that repair and replacement of parts (seals, snubbers, actuator, expendable release devices)

can be done efficiently. Estimated annual maintenance costs shall not exceed 20% of the corresponding diaphragm replacement costs.

## 5.3 Function of the Valve Installation

The mechanical quick-opening valve will replace the existing 48 in. I.D. Mylar diaphragm in providing flow initiation for the MSFC High Reynolds Number Wind Tunnel. Use of the quick-opening valve will eliminate the cost of the Mylar diaphragms and the cost of assembling and installing diaphragms for each test.

## 6.0 COST ESTIMATE

The costs of proceeding from the concept and criteria (described in Sections 5.0 and 6.0 respectively) to an operating valve system fall into two primary categories; engineering and construction.

The engineering costs include the overall design of the valve and the modifications required in the existing facility to permit its installation. We have also included in the engineering cost, the cost of detailed design and verification by test of the release mechanism and seal configurations.

The construction costs include the detail piece part design of the valve parts (i.e. the production of shop drawings) and fabrication of the valve per se, the modifications to the existing facility per the engineering design, and the costs of installation and check out.

These costs are based on in house estimates using data from current similar projects and are "today" costs. An escalation factor of 13% has been added to carry them forward to the mid point of construction, and a 10% contingency added to account for unanticipated requirements. The contingency is relatively low because of our familiarity with the facility and because we have included verification by test of the critical concept areas in the engineering estimate.

The escalation period is based on the following schedule:

| | | |
|---|---|---|
| Engineering | start | 11-1-83 |
| | complete | 5-1-84 |
| Construction | start | 7-1-84 |
| | complete | 7-1-85 |

The cost breakdown is given below:

| | |
|---|---|
| **Engineering Costs** | |
| - Overall Engineering Design | 83,000 |
| - Release Mechanism | |
| Detail Design & Test | 55,000 |
| - Seal | |
| Detail Design & Test | 33,000 |
| Total | 171,000 |
| | |
| **Construction Costs** | |
| - Valve | |
| Detail Design & Fabrication | 305,000 |
| - Existng Facility | |
| Modifications | 68,000 |
| - Installation & Checkout | 32,000 |
| Total | 405,000 |
| | |
| Escalation to 1-1-85 @ 13% | 53,000 |
| Contingency @ 10% | 40,000 |
| | |
| Total Construction Cost | 498,000 |
| | |
| SIES @ 5% | 25,000 |

# 7.0 LIST OF REFERENCES

1. Ludwieg, H., "Tube Wind Tunnel - A Special Type of Blowdown Tunnel," AGARD Report 143, July 1957

2. Gwin, H.S., "The George C. Marshall Space Flight Center High Reynolds Number Wind Tunnel Technical Handbook,". NASA TM X-64831, Revised October 1975

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FIGURES

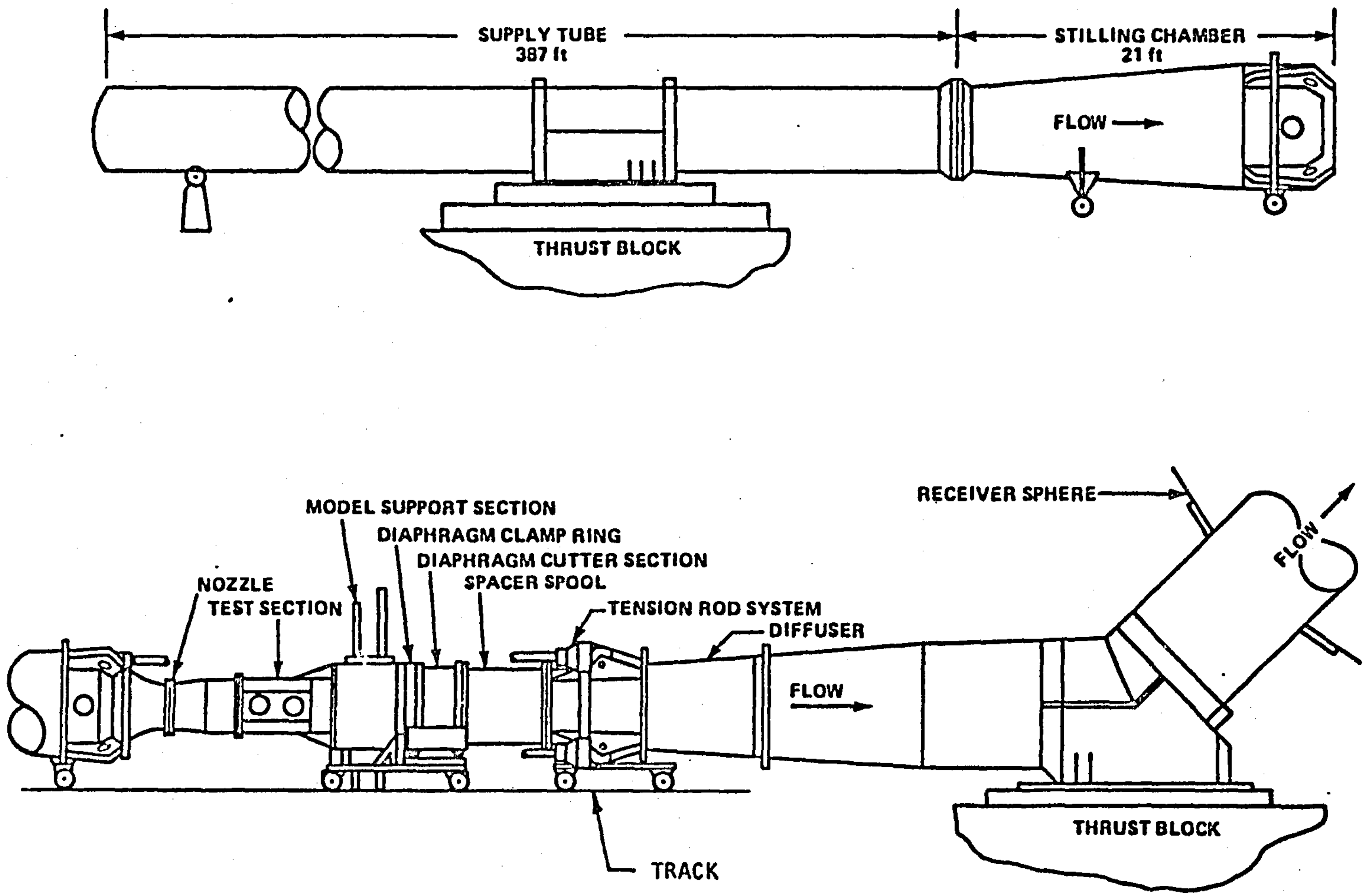


Figure 1. High Reynolds number wind tunnel. (current configuration)

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FLUIDYNE ENGINEERING CORPORATION

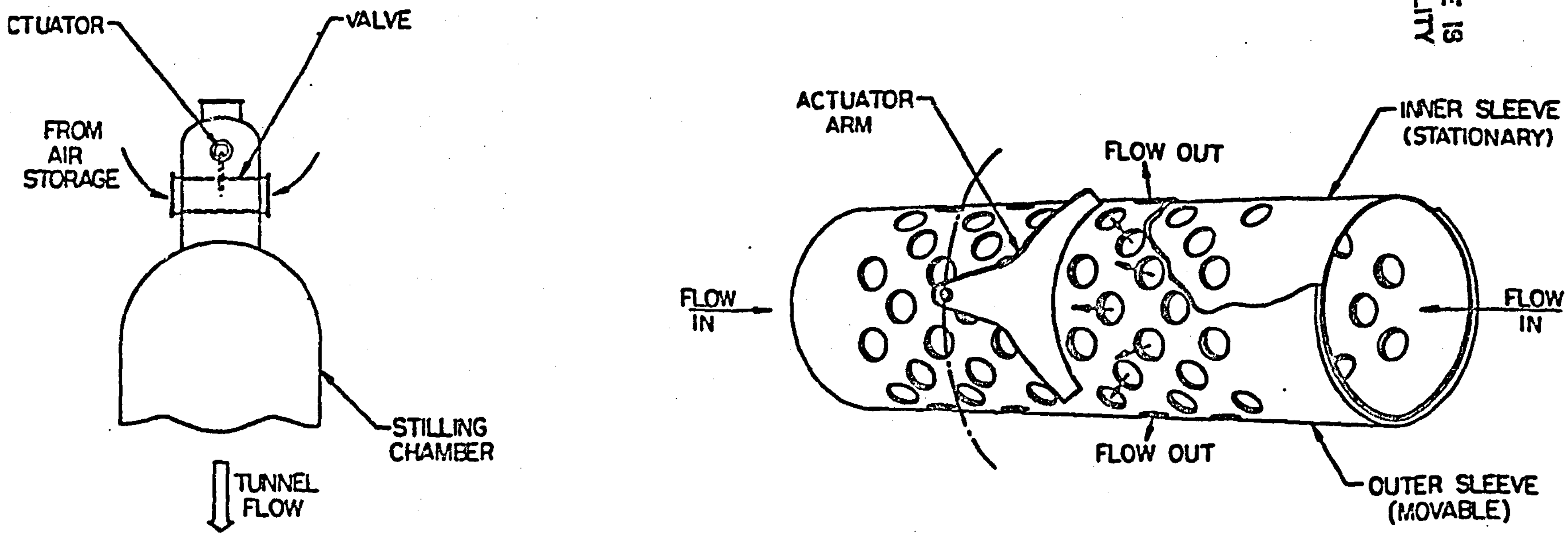



FIGURE 2 FLUIDYNE PERFORATED SLEEVE
WIND TUNNEL CONTROL VALVE

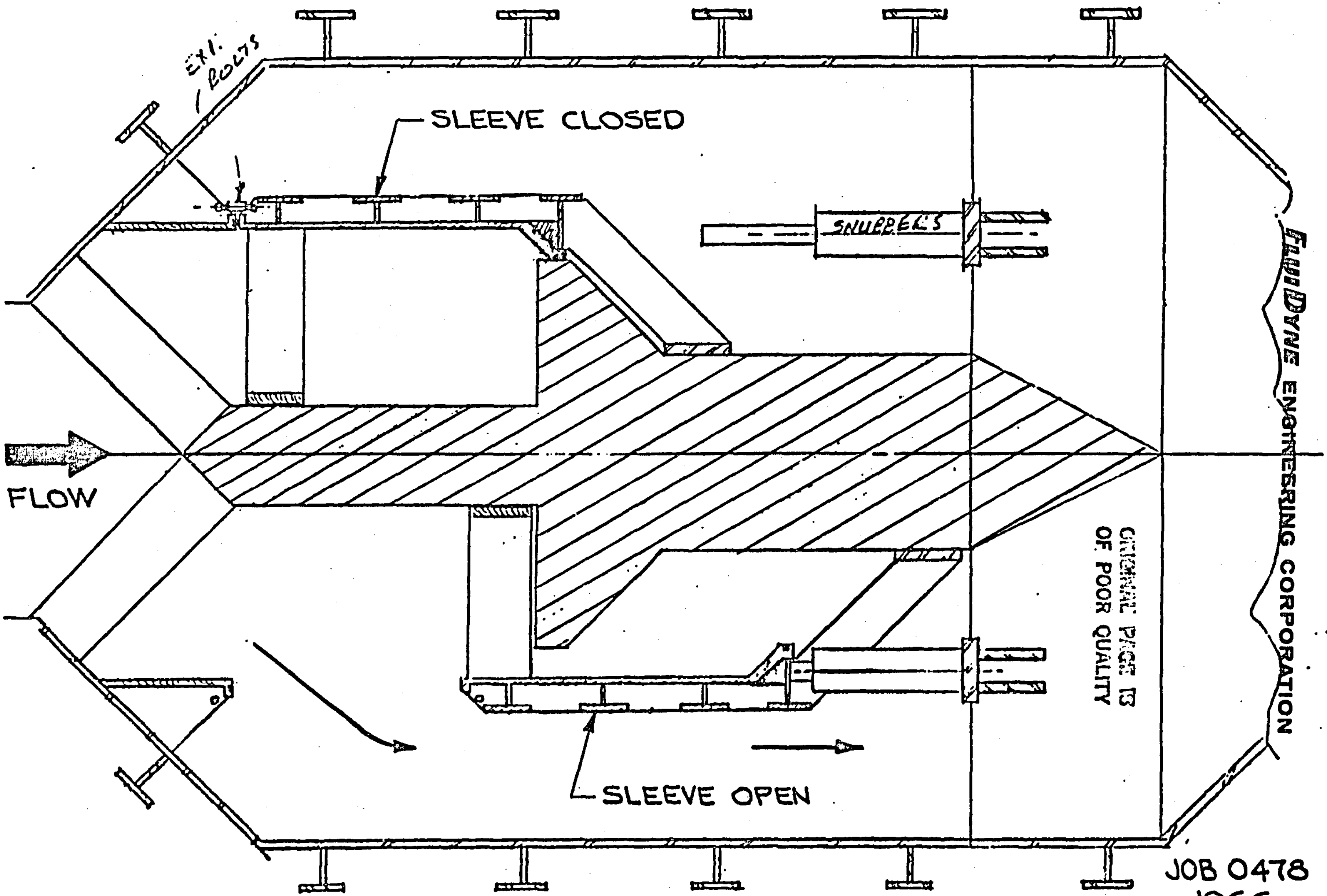
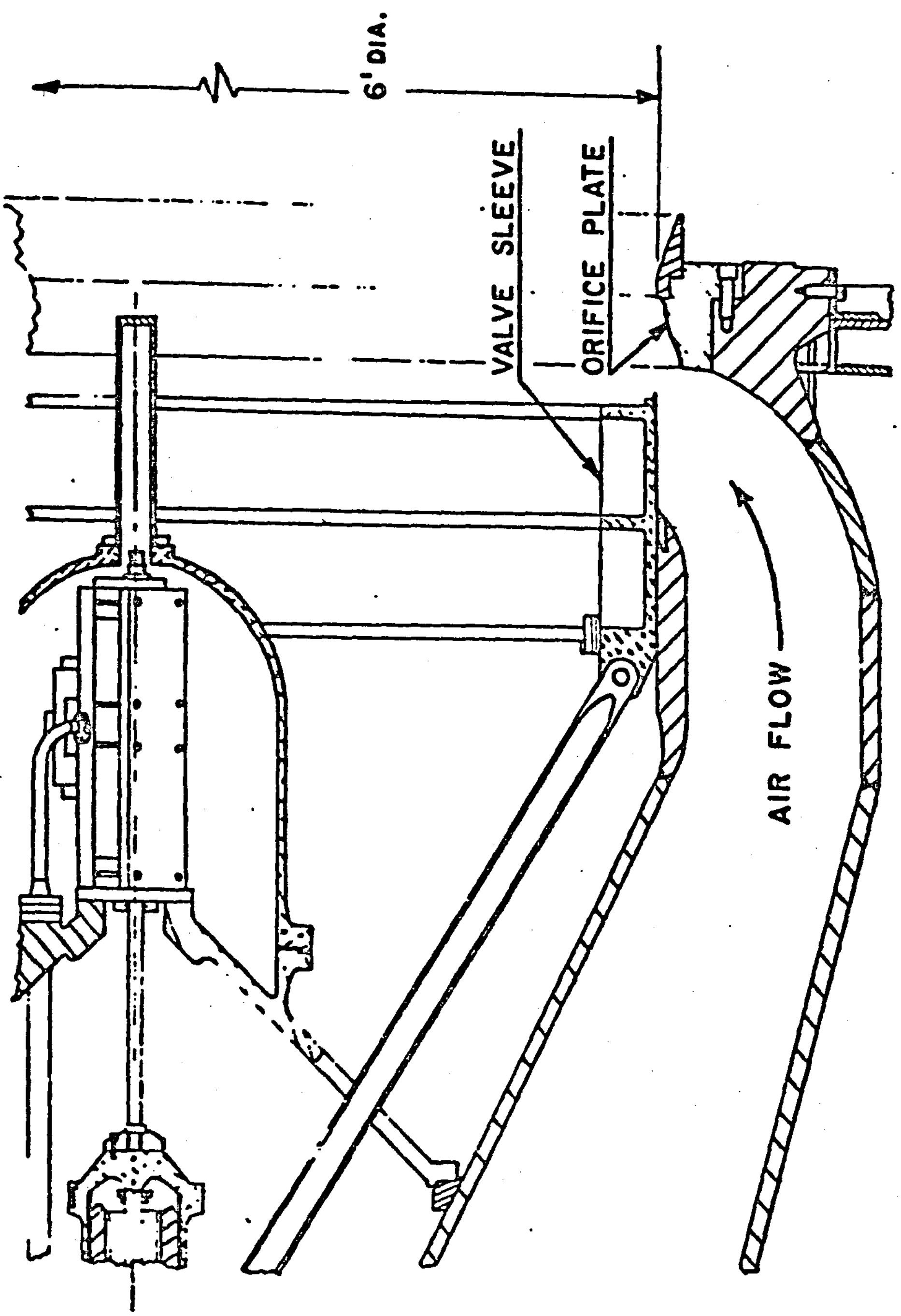
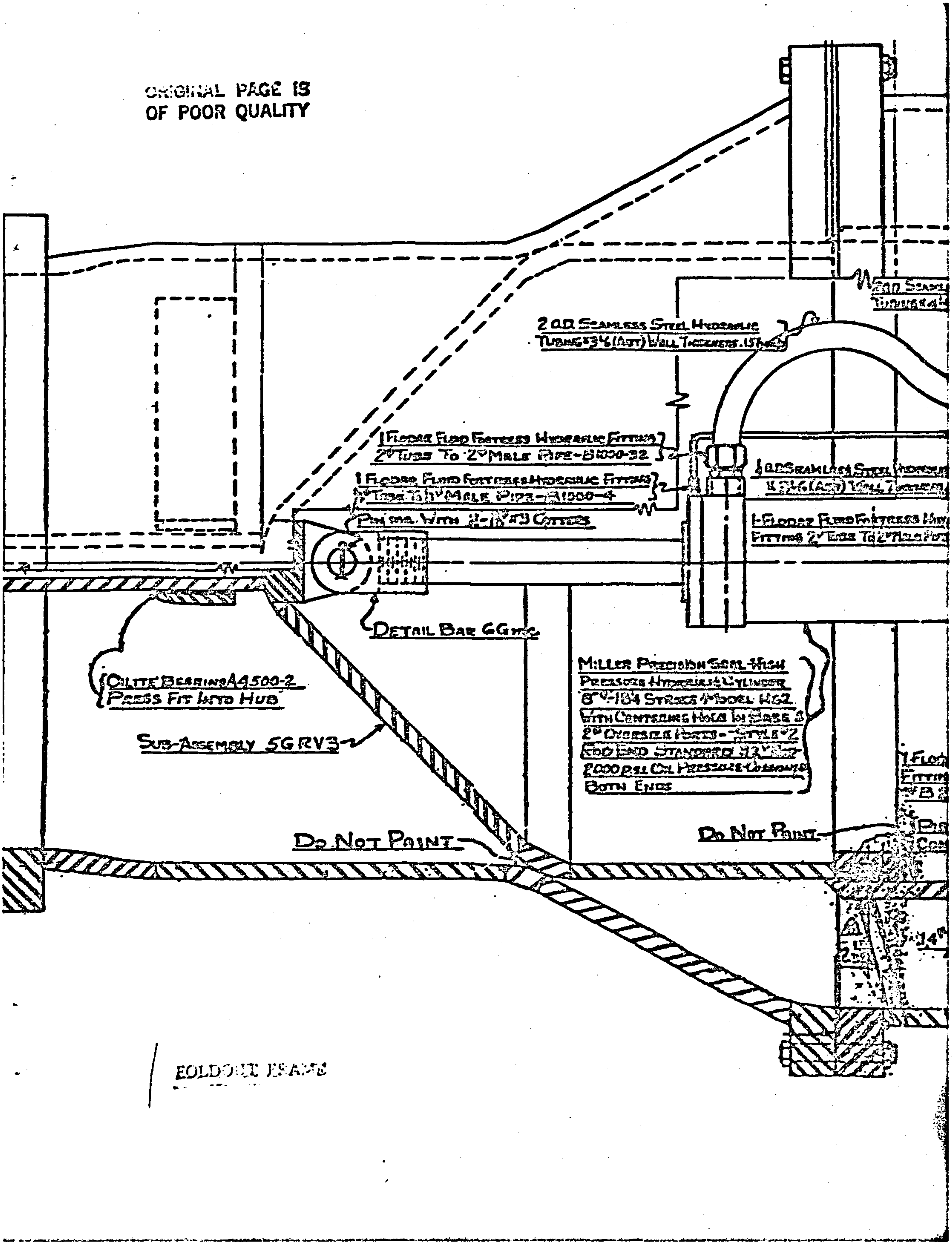



FIGURE 3 EARLY SLEEVE VALVE CONCEPT




VALVE SLEEVE AND ORIFICE PLATE OF CONTROL VALVE
FIVE FOOT WIND TUNNEL

FIGURE 4




FOLDOUT FRAME

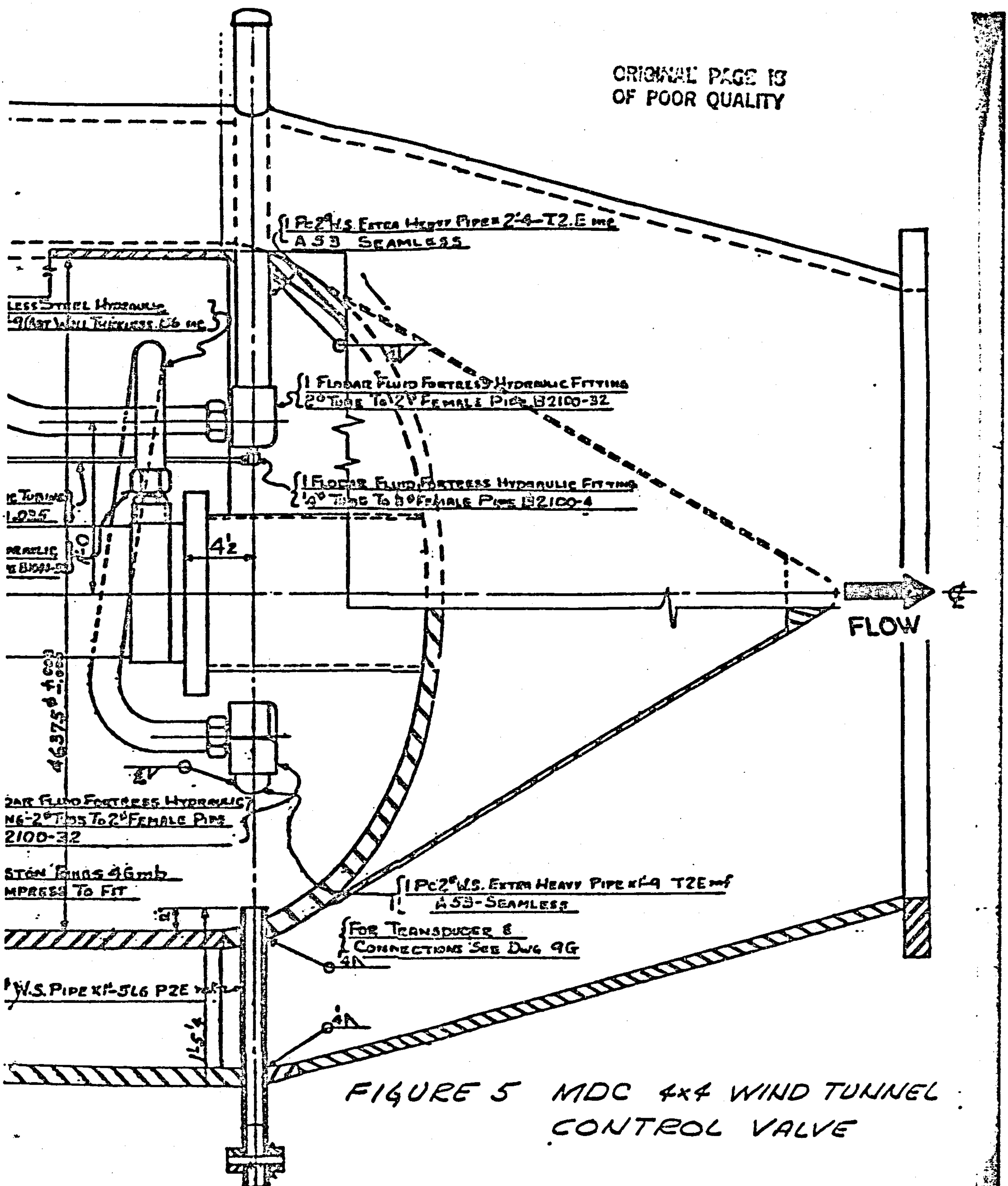



FIGURE 5 MDC 4x4 WIND TUNNEL CONTROL VALVE

2 FOLDOUT FRAME

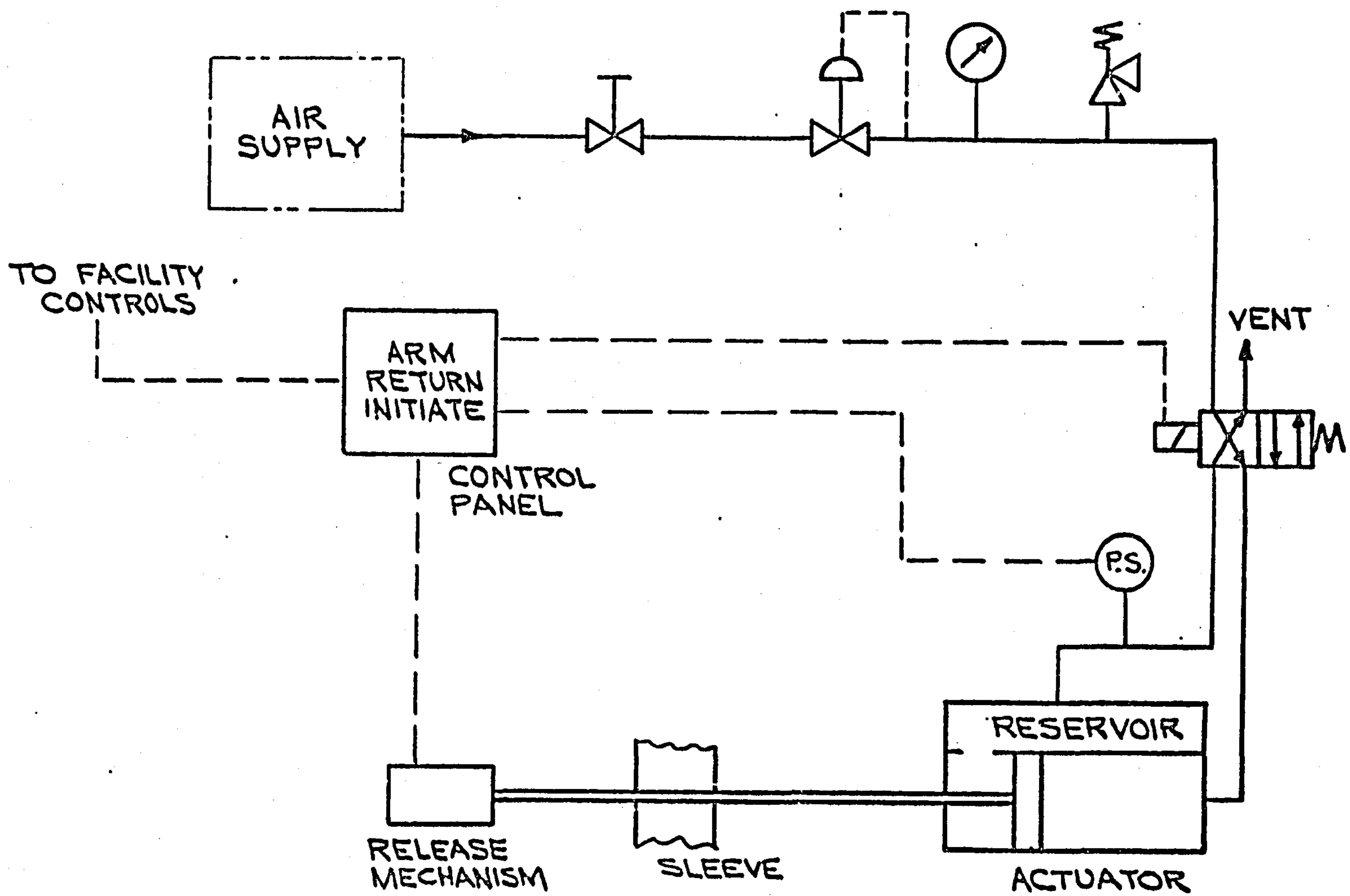
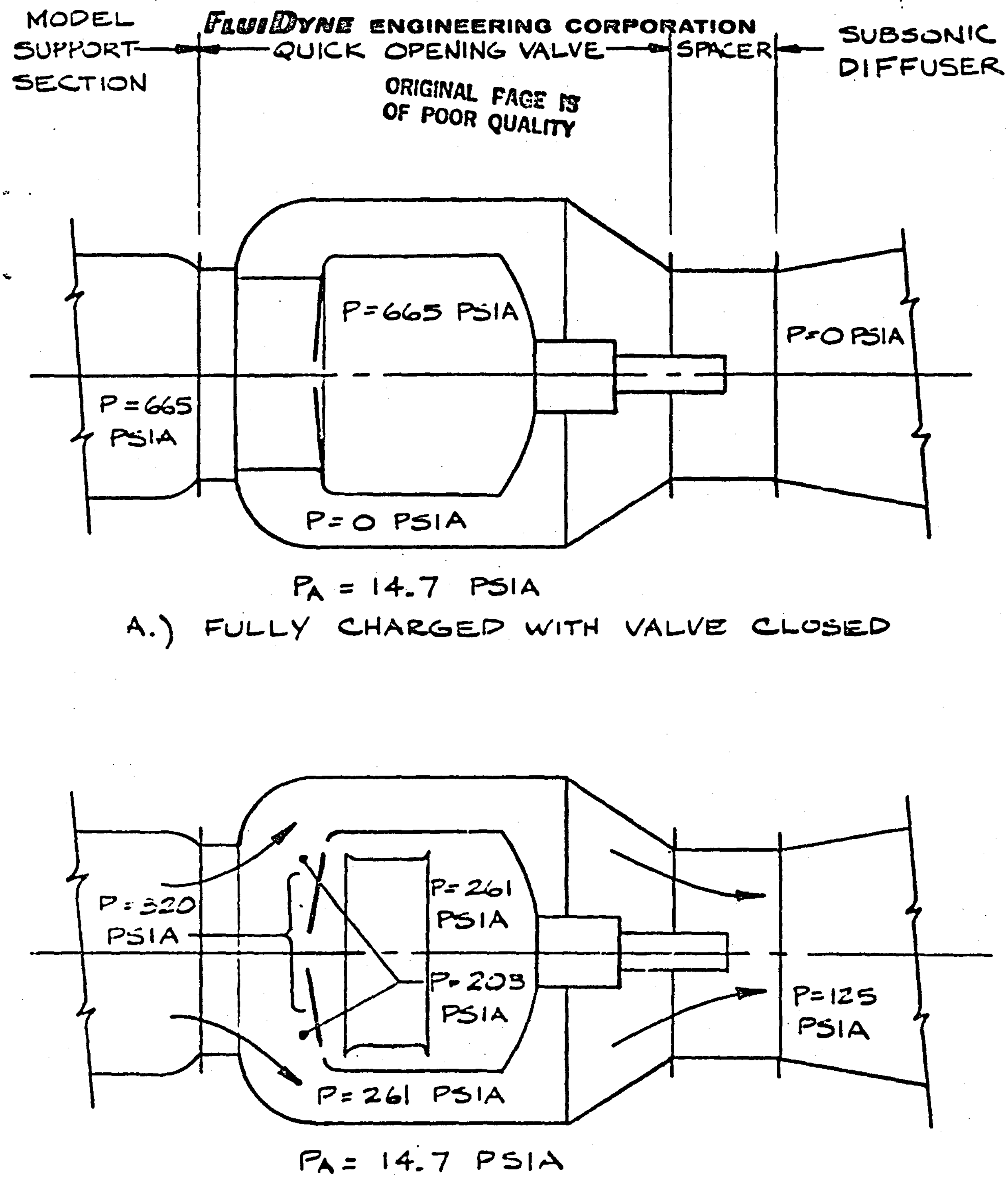



FIGURE 6 CONTROL SCHEMATIC




A.) FULLY CHARGED WITH VALVE CLOSED

B.) NORMAL OPERATION DURING RUN

FIGURE 7 PRESSURE LOADS ON RING SLEEVE VALVE FOR NORMAL OPERATING CONDITIONS

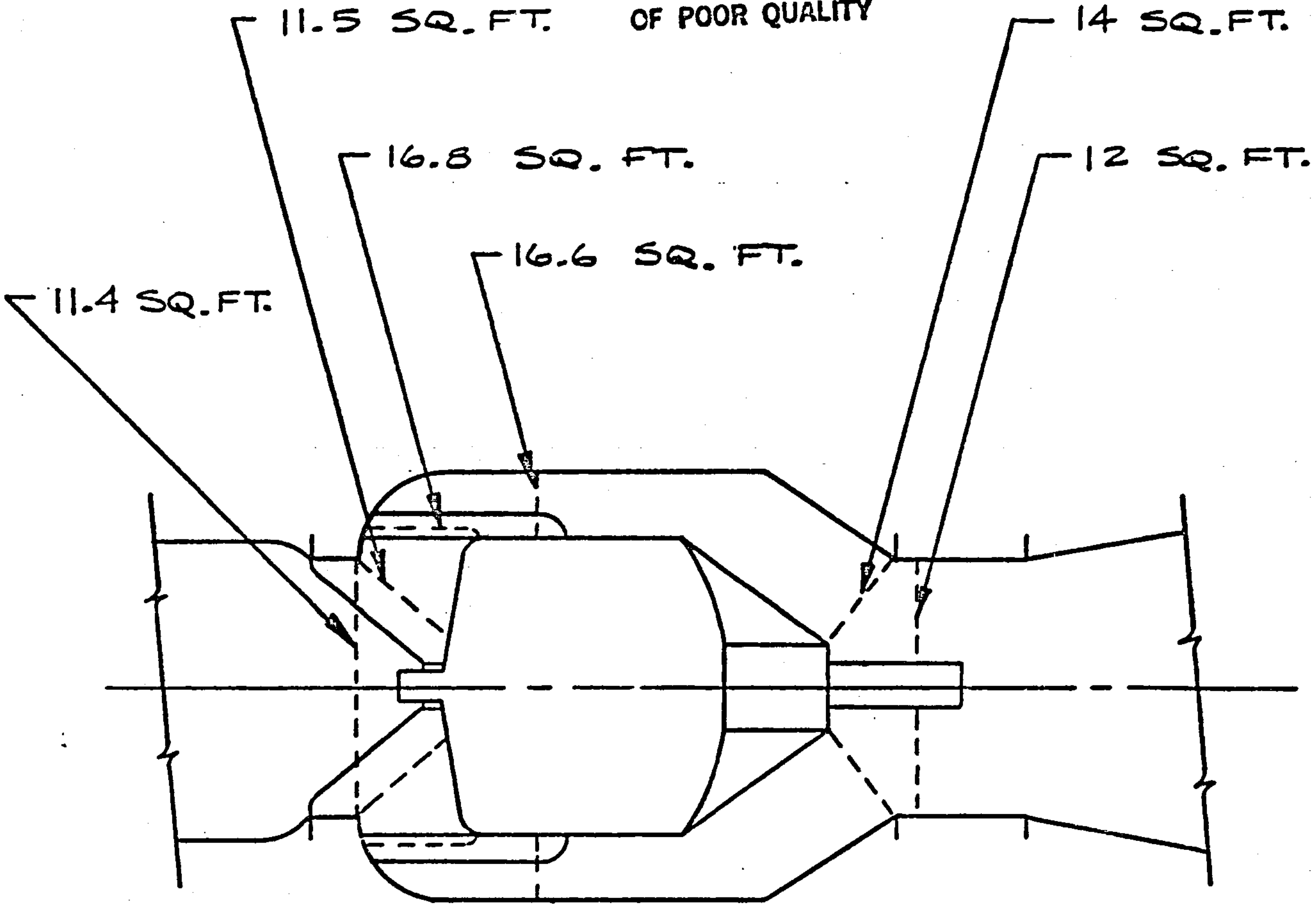



FIGURE 8 DISTRIBUTION OF GEOMETRIC FLOW AREA THROUGH VALVE (ADEQUATE FOR PRICING, BUT NOT COMPLETELY OPTIMIZED)

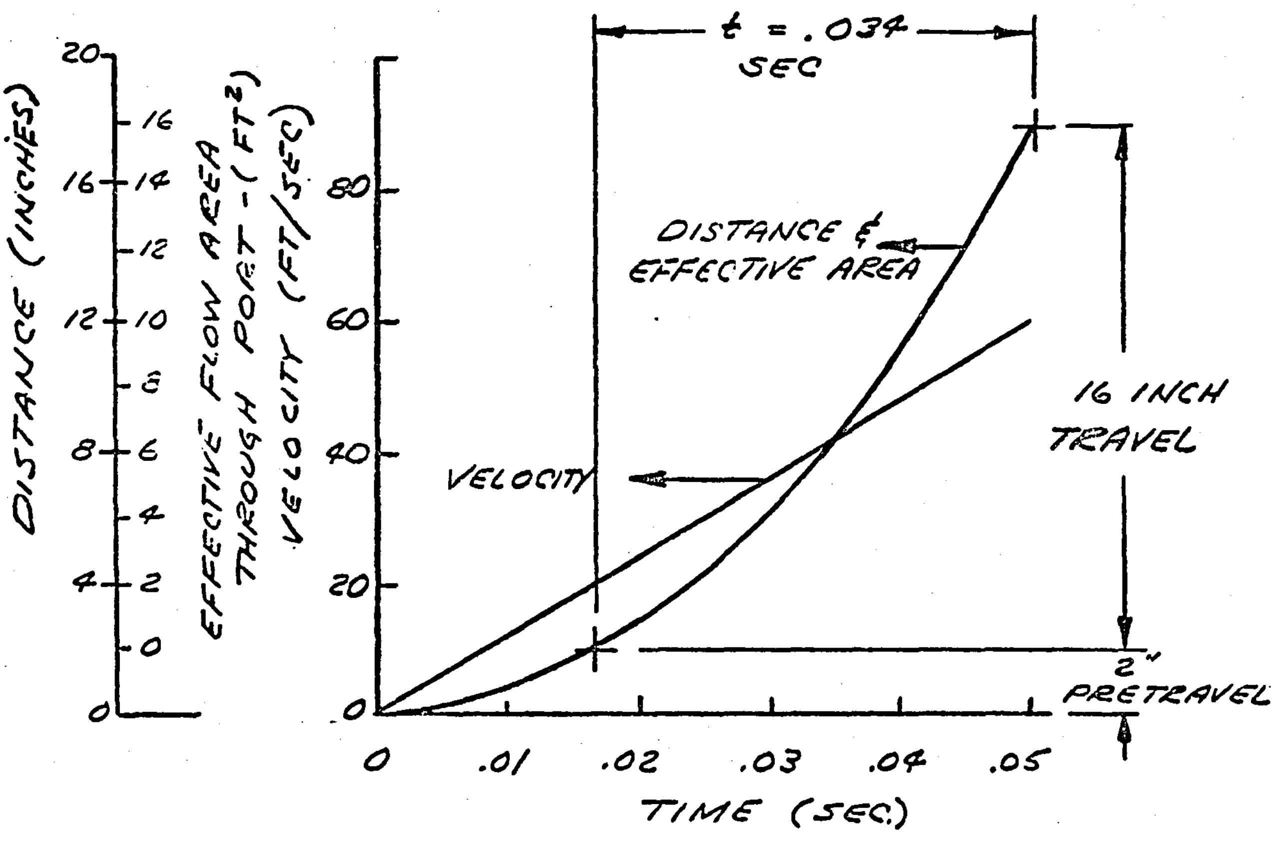
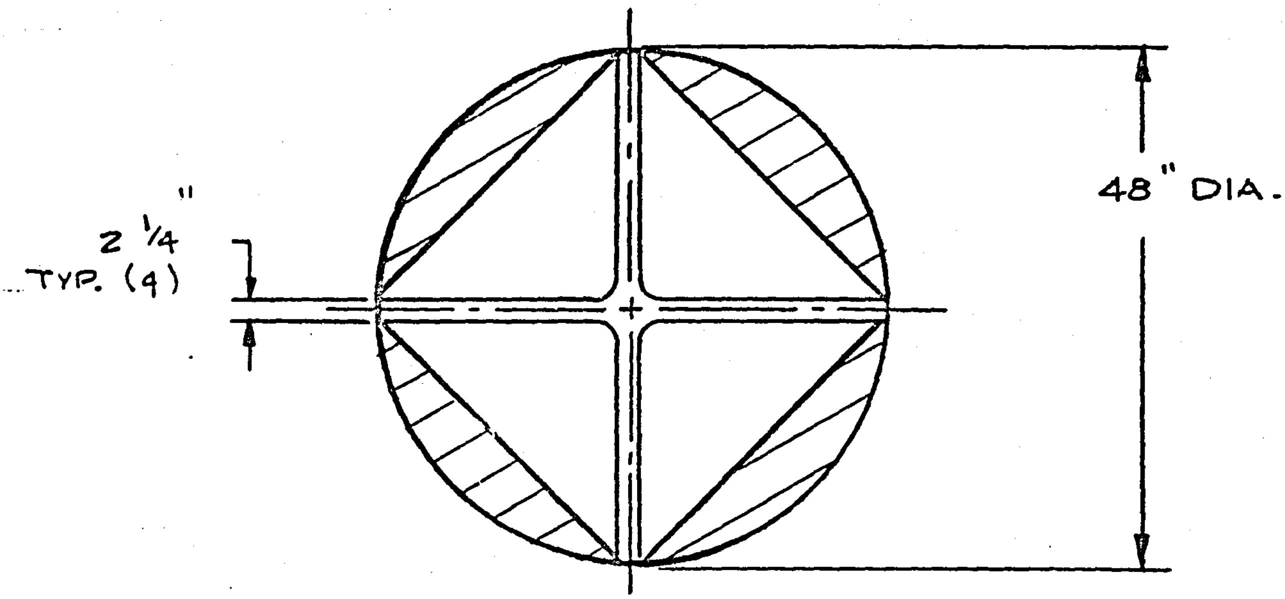



FIGURE 9 RING SLEEVE TRAVEL, EFFECTIVE PORT AREA AND VELOCITY VERSUS TIME

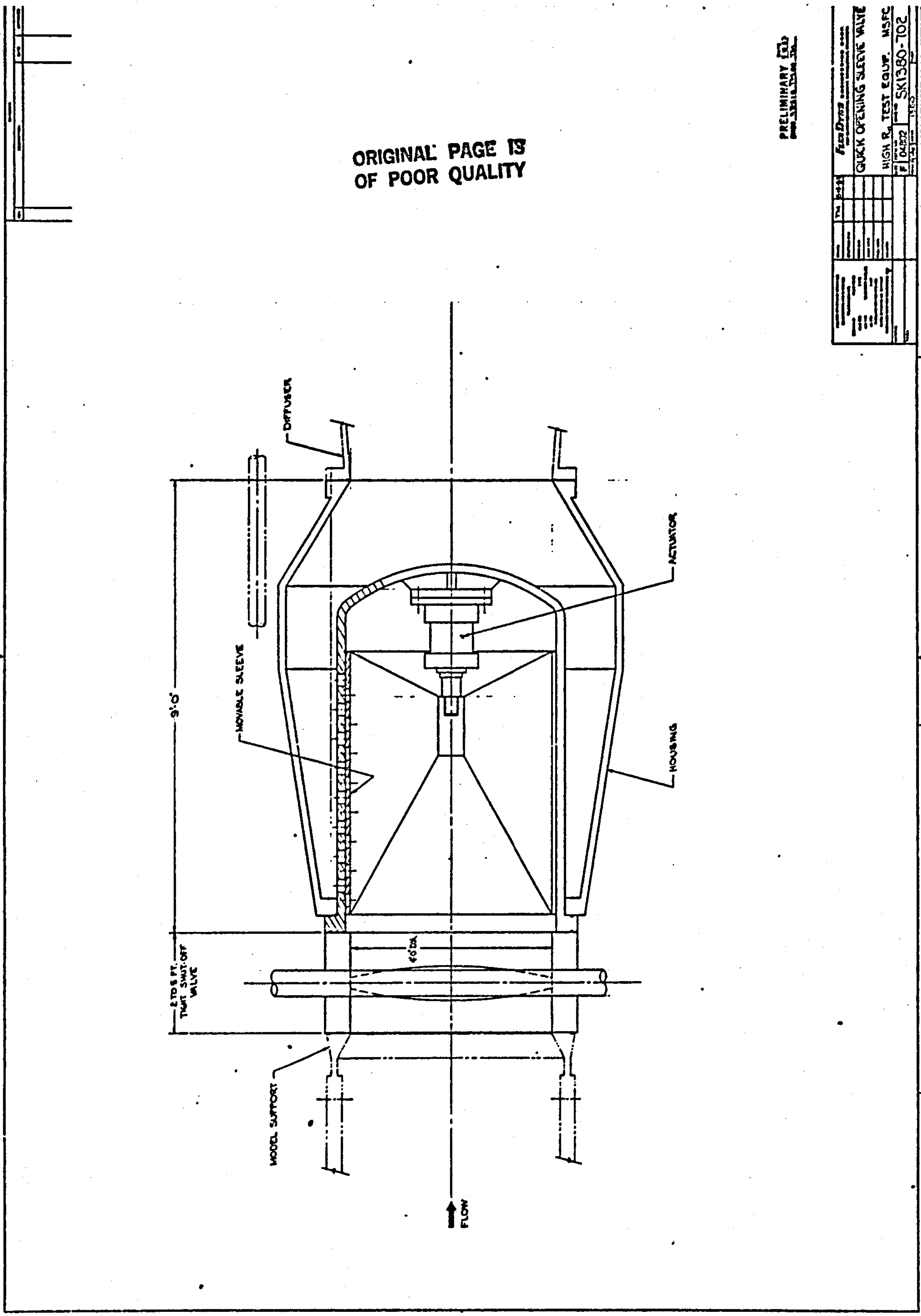



SHADED AREA REPRESENTS DIAGHRAM BLOCKAGE

AS SHOWN NET EFFECTIVE AREA = 7.3 SQ. FT.

PROBABLE ACTUAL NET AREA = 9 SQ. FT.

FIGURE 10 MYLAR BURST DIAPHRAGM
NET EFFECTIVE AREA


PRELIMINARY
QUICK OPENING SLEEVE VALVE
HIGH R TEST EQUIP. MSFC
SK1380-702
DIFFUSER
ACTUATOR
MOVABLE SLEEVE
HOUSING
9'-0"
6'-0" DIA
2 TO 5 FT. TIGHT SHUT-OFF VALVE
MODEL SUPPORT
FLOW

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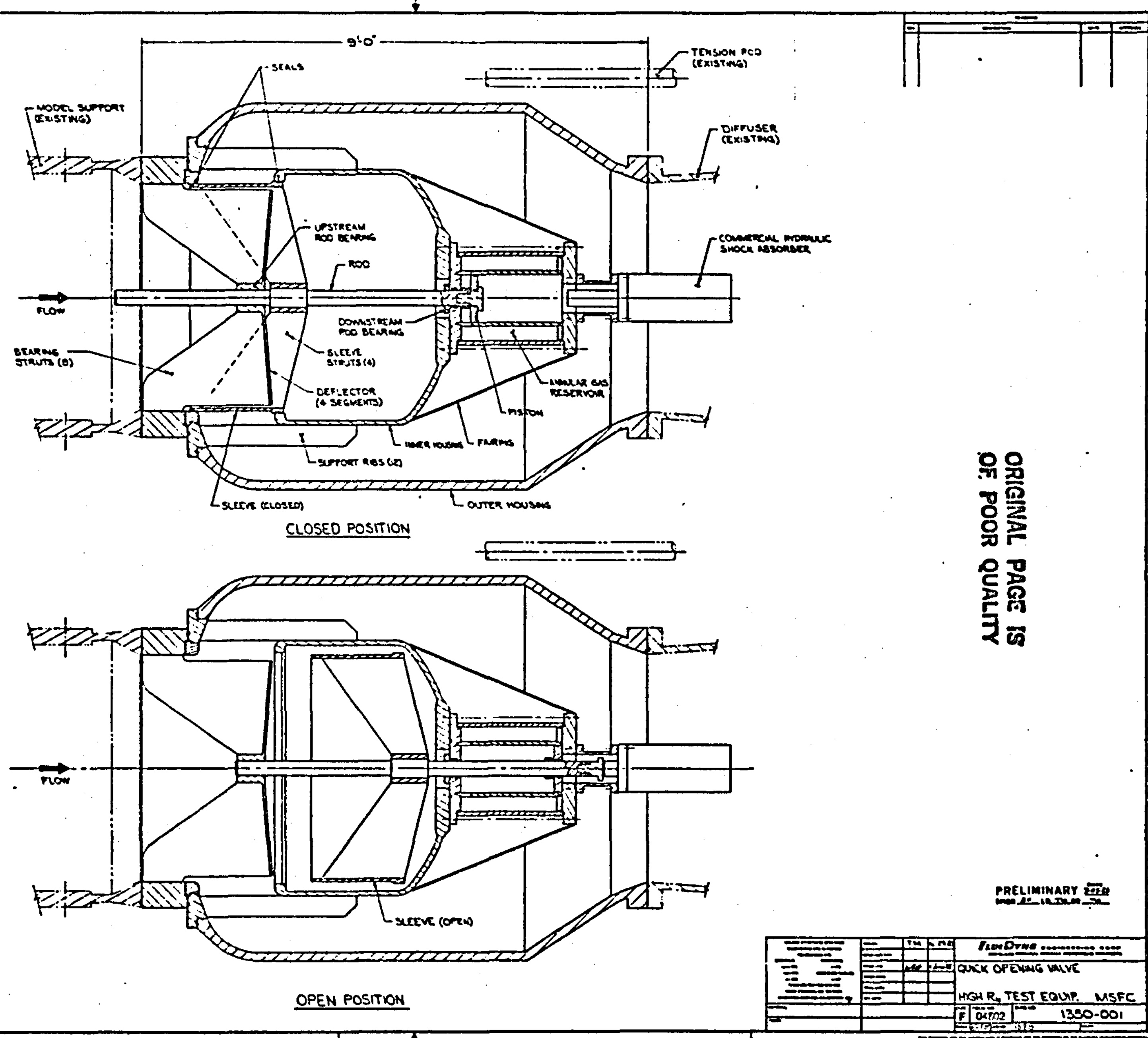

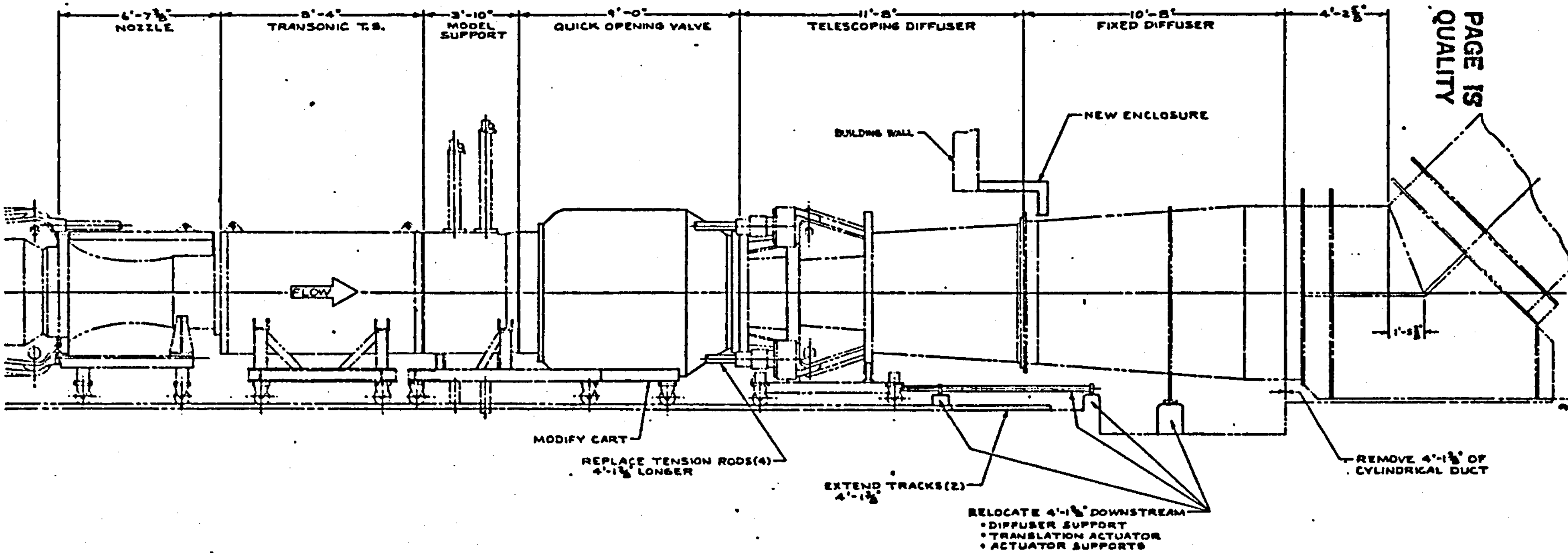


ELEVATION

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PRELIMINARY

FluiDyne

FACILITY LAYOUT WITH QUICK OPENING VALVE

HIGH $R_N$ TEST EQUIP. MSFC

F 04302 1380-002

END

DATE

FILMED

OCT 11 1983

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